Attorney's Docket No.: 42P12980DC

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application for:	
Alex Levin, et al.	Examiner: Siek, Vuthe
Application No.: 10/814,398	Art Group: 2825
Filed: March 31, 2004	Conf. No.: 5375
For: **A METHOD AND APPARATUS FOR ANALOG COMPENSATION OF DRIVER OUTPUT SIGNAL SLEW RATE AGAINST DEVICE IMPEDANCE VARIATION**	

DECLARATION PURSUANT TO 37 C.F.R. §1.131

Mail Stop Amendment
Commissioner for Patents
P. O. 1450
Alexandria, VA 22313-1450

Dear Sir:

I, Alex Levin, hereby declare that:

1. I am a citizen of the United States of America.
2. I currently reside at Tacoma, WA.
3. I am currently an employee of Intel Corporation in Santa Clara, California.
4. I have been an employee of Intel Corporation since 6-16-97.
5. My current title at Intel Corporation is Senior Staff Engineer.
6. I am a co-inventor of the above-identified patent application.

7. I have reviewed the U.S. Patent No. 7,019,551, issued to Biesterfeldt, et al. ("Biesterfeldt"), which was filed on September 30, 2002, and claims priority to Provisional Application No. 60/344,163, filed on December 27, 2001. The Examiner cites Biesterfeldt against the claims of the above-identified application.

8. The invention disclosed and claimed in the above-identified patent application was conceived in the United States of America at least as early as July 19, 2001, as evidenced by the Intel Corporation Invention Disclosure having ID #20684 (a copy of which is attached herein). This document was reduced to writing internally within Intel Corporation at least as early as the date on the document; i.e., July 19, 2001. This document demonstrates conception of the claimed invention of the instant application. Between at least July 19, 2001 and its constructive reduction to practice by the filing of U.S. Patent No. 6,576,376 (the parent of the above-captioned patent application) on January 3, 2002, I directed simulations and various testing in a diligent effort to reduce the invention to practice. Therefore, the conception and diligence towards reduction to practice of the invention disclosed and claimed in the above-identified patent application occurred prior to the filing date of Biesterfeldt.

9. The documents provided herewith are confidential. It is Intel Corporation's practice to maintain in secrecy all confidential documents. I believe that the documents have at all times prior to the filing date of the above-captioned application been maintained in a confidential manner.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States

Code, and that such willful false statements may jeopardize the validity of the above-identified application or any patent issued thereon.

Respectfully submitted,

Dated: 9-24-07

Alex Levin

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Rev. 15, 8/00

INTEL INVENTION DISCLOSURE

ATTORNEY-CLIENT PRIVILEGED COMMUNICATION

located at http://legal.intel.com

DATE: 7/19/01 20684 Chipset Graphics / IAG / DPG / CSE

It is important to provide accurate and detailed information on this form. The information will be used to evaluate your invention for possible filing as a patent application. When completed and signed, please return this form to the **Legal Department at JF3-147. You can submit electronically via e-mail to "invention disclosure submission" if all of the information is electronic, including drawings and supervisor approval.** If you have any questions, please call **264-0444.**

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***If you are unsure of this information, please discuss with your manager.**

(PROVIDE SAME INFORMATION AS ABOVE FOR EACH ADDITIONAL INVENTOR)

2. Title of Invention: Analog Self Compensation of I/O Driver Slew Rate Against Device Impedance Variation

3. What technology/product/process (code name) does it relate to (be specific if you can): Integrated circuits using on-chip signal termination

4. Include several key words to describe the technology area of the invention in addition to # 3 above: resistance variation, slew rate variation, slew rate control, crowbar current, high-speed I/O design, bus termination

5. Stage of development (i.e. % complete, simulations done, test chips if any, etc.): Simulations done, the described mechanism will be present in upcoming ICH4 product

6. (a) Has a description of your invention been, or will it shortly be, published outside Intel:

NO: X YES: ____ If YES, was the manuscript submitted for pre-publication approval?

IDENTIFY THE PUBLICATION AND THE DATE PUBLISHED: ____

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JUL 19 2001
PATENT DATABASE GROUP
INTEL LEGAL TEAM

(b) Has your invention been used/sold or planned to be used/sold by Intel or others?

NO: X YES: ____ DATE WAS OR WILL BE SOLD: Q3 2002

(c) Does this invention relate to technology that is or will be covered by a SIG (special interest group)/standard/ or specification?

NO: ________ YES: __X__ Name of SIG/Standard/Specification: T13 (ATA specification)

(d) If the invention is embodied in a semiconductor device, actual or anticipated date of tapeout? 8/31/01

(e) If the invention is software, actual or anticipated date of any beta tests outside Intel ________

7. Was the invention conceived or constructed in collaboration with anyone other than an Intel blue badge employee or in performance of a project involving entities other than Intel, e.g. government, other companies, universities or consortia? NO: __X__ YES: _____ Name of individual or entity: ________

8. Is this invention related to any other invention disclosure that you have recently submitted? If so, please give the title and inventors: No

****

PLEASE READ AND FOLLOW THE DIRECTIONS ON HOW TO WRITE A DESCRIPTION OF YOUR INVENTION

Please attach a description of the invention to this form and include the following information:

1. **Describe in detail what the components of the invention are and how the invention works.**
2. **Describe advantage(s) of your invention over what is done now.**
3. **YOU MUST include at least one figure illustrating the invention. If the invention relates to software, include a flowchart or pseudo-code representation of the algorithm.**
4. **Value of your invention to Intel (how will it be used?).**
5. **Explain how your invention is novel. If the technology itself is not new, explain what makes it different.**
6. **Identify the closest or most pertinent prior art that you are aware of.**
7. **Who is likely to want to use this invention or infringe the patent if one is obtained and how would infringement be detected?**

HAVE YOUR SUPERVISOR READ, DATE AND SIGN COMPLETED FORM OR FORWARD IT ELECTRONICALLY VIA E-MAIL TO "INVENTION DISCLOSURE SUBMISSION"

DATE: ________________ SUPERVISOR: ________________________________

BY THIS SIGNING, I (SUPERVISOR) ACKNOWLEDGE THAT I HAVE READ AND UNDERSTAND THIS DISCLOSURE, AND RECOMMEND THAT THE HONORARIUM BE PAID

Patent Disclosure:

Self-Compensation of On-Chip Termination Resistor Variation Using Regulated Crowbar Current

Alex Levin and Kim Soi Er

Background

High-speed I/O buffers can improve transmitted and received signal quality through the use of on-chip resistive termination. For high-density applications, designers often use termination resistors made from Nwell material, due to its relatively high resistivity. However, materials and processing used to create the resistive elements are subject to wide variation. Without external compensation, the resistance of the termination device can easily vary by 300%. Because output signals are driven through these termination resistors, the effect of the resistance variation on output signal slew rate can be significant. It is therefore necessary to compensate the output driver's slew rate according to the strength of the on-chip termination resistor.

Invention

The proposed method is used to adjust output driver signal slew rate in accordance with variations in the resistivity of the material used for the on-chip termination resistor. The compensation is analog in nature, meaning a change in the resistivity of the material will induce a proportional change in the output driver's slew rate.

The typical output driver is divided into pull-up and pull-down portions, using PMOS transistors for the pull-up, and NMOS transistors for the pull-down. The driver's pull-up and pull-down sections are organized into groups that are turned on in succession to provide basic control of output slew rate. The I/O buffer pre-driver sends the necessary control signals to the pull-up and pull-down. High-speed drivers often break the pull-up and pull-down sections into strong and weak groups. To control slew rate, the weak legs turn on first, followed some time later by the stronger legs.

In order to further control the signal slew rate, the some of the pull-up legs, for instance, may be left on for all or a portion of a high-to-low signal transition. The result is a "crowbar current" which flows from the power supply to the ground, rather than out onto the bus line to charge the receiver load. Higher crowbar current results in a slower transition, since less current will flow onto the bus line to charge the load. Controlling the amount crowbar current effectively controls the signal slew rate.

This invention places a compensation resistor (a scaled down version of the type used in the driver's on-chip termination resistor) in series with the driver legs that are turned on to produce the crowbar current. When the compensation resistor is weak, less crowbar current will flow. More current will be driven out onto the bus, and the resulting slew rate will be faster. When the compensation resistor is strong, more crowbar current will flow from power to ground, less current will flow onto the bus to charge the receiver load, and the resulting slew rate will be slower.

This simple control mechanism counteracts the (unwanted) variation that the main termination resistor imposes on the driver slew rate. Without compensation, high series termination resistance will cause a slow signal transition, since the capacitive receiver load will charge/discharge more slowly. Driver current is limited by the high resistance in the charge/discharge path. The converse is true for low series termination resistance—the load will charge/discharge quickly because of the increased current that the driver can source/sink.

By employing the compensation mechanism discussed above, the major contributor to slew rate variation is used to correct its own influence on that output slew rate. Left alone, a weak termination resistor causes a slow signal transition; with this compensation method, that same weakness is used to decrease the output driver's crowbar current, thus speeding up the edge rate. The same effect is achieved in the case of a low resistance termination device. The lower resistance compensation resistor allows more crowbar current to flow, lowering the edge rate.

The figure 1 illustrates the operation of a standard I/O buffer, and shows the pre-driver signals that control its operation. NDRVG0 and NDRVG1 control the NMOS pull-down section; PDRVG0 and PDRVG1 control the PMOS pull-up section. In this example, the NDRVG0 and NDRVG1 signals turn off prior to a rising transition, so there is no crowbar current. The same is true for a falling transition; the PDRVG0 and PDRVG1 signals turn off prior to the pull-down signals being asserted.

Figure 2 shows the operation of an I/O buffer that employs the self-compensation scheme to counteract the Nwell resistor variation effect on slewrate. In a rising transition, the weaker NMOS leg, controlled by NDRVG1 is left on during the transition. During this time, crowbar current flows from the pull-up transistor down to ground through the pull-down transistor. With an "Nwell compensation resistor" added into the pull-down leg, the amount of crowbar current is controlled by the Nwell resistivity. When resistivity is low, more crowbar current will flow to ground. Less current will flow to the pad to charge the load, lowering the overall slew rate. The same mechanism controls the falling edge slew rate. Figure 3 shows the pre-driver and signals controlling the transitions.

The N-well compensation resistor is sized so that its resistance is significantly greater than that of the transistor driver in the crowbar leg. By doing so, the process sensitivity of the N-well resistor will be dominant in the regulation of the crowbar current. Power consumption limitations will guide the designer in the selection of the overall size of the N-well resistor and driving device in the crowbar leg. Experimentation has shown that keeping the crowbar leg at least 1/3 the strength of the primary N-well termination resistor is necessary to ensure that the compensation scheme is effective in controlling output slew rate.

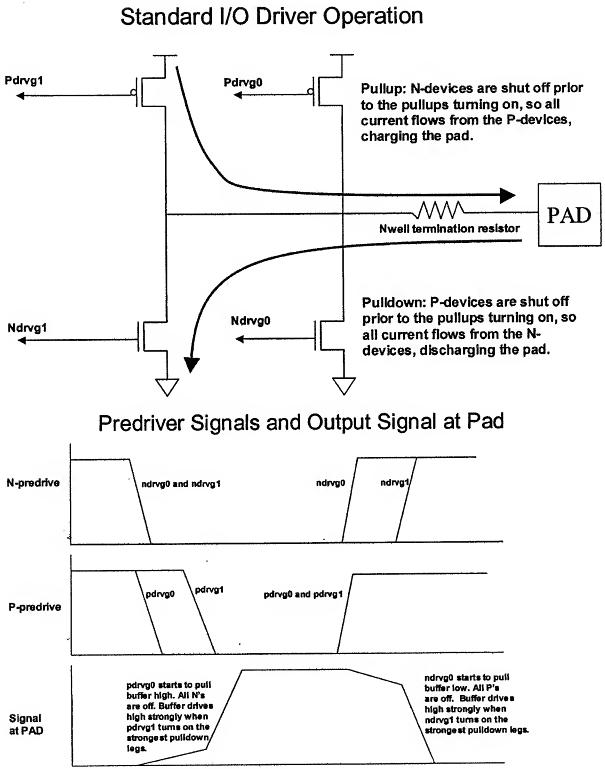
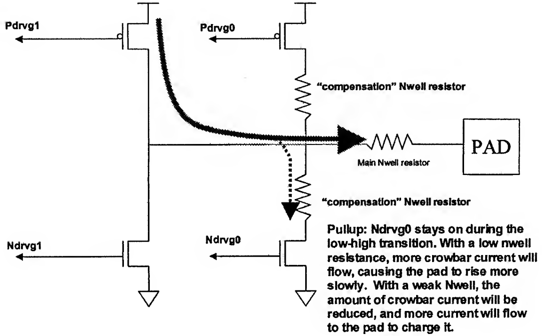


Figure 1: Operation of a standard I/O buffer

New Self-Compensated I/O Driver Operation



New Self-Compensated I/O Driver Operation

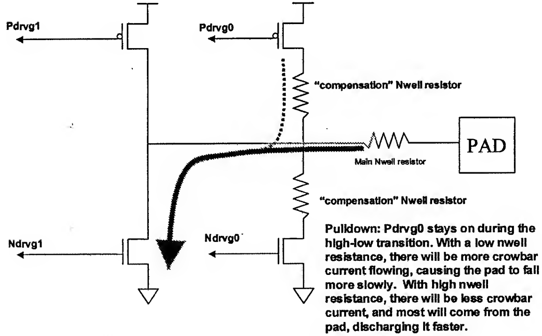


Figure 2: Slew rate self-compensation achieved by regulated crowbar current

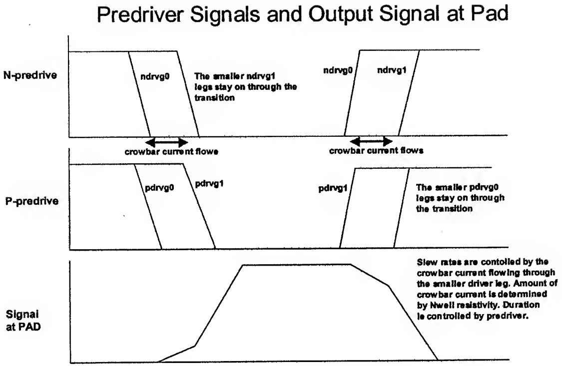


Figure 3: Pre-driver signals which allow the necessary crowbar current for the self-compensation mechanism. Crowbar current is determined by N-Well and driver leg resistance together.

Advantages Over What Is Done Now

Compensation mechanisms to control driver impedance our output slew rate generally rely on external resistors for calibration. That adds the costly requirement of an extra pin in the device. This method works without any extra pins being added to the device.

The problem of excessive termination resistor variation is best addressed through an analog solution; specifically, one which will adjust output slew rate in proportion to the variation of the termination resistor. Since both the termination resistor and the compensation resistors are produced from the same material, under the same manufacturing process conditions, the compensation resistor will be an accurate gauge of the termination resistivity. Small changes in the compensation resistor will cause small changes in the output slew rate. Larger variation will produce an increased compensation effect.

Value to Intel

Intel typically uses an "Nwell resistor" structure for on die termination. This highly resistive structure is simple to create, and consumes a relatively small area (compared to a poly resistor), yet is prone to wide variation in resistivity. Most sensitive high-speed

output drivers use external compensation (requiring extra pins at higher manufacturing cost) to maintain correct functionality across the wide resistive range of the Nwell resistor. This invention allows output drivers to use the Nwell resistor, and still produce in-spec slew rates without additional package pins for slew rate compensation. Since pin count is a considerable component of overall manufacturing cost, the elimination of pins is always beneficial.

Compensation circuits, particularly ones which employ a digital approach, have historically been trouble spots, due to their complexity, the need for calibration, and their potential to interfere with normal buffer operation. This method is much less complex, and represents a lower risk solution to slew rate compensation.

ICH4 (I/O Control Hub 4) has used this mechanism in the IDE output drivers. This implementation has provided up to 25% greater control over slew rate than has been achieved through other control schemes.

Novelty

The invention provides true analog compensation for the effects of termination resistance on the output driver slew rate, and does not require any additional pins to do so.

The invention makes use of an already present feature of output buffers (crowbar current), which is often considered undesirable, to produce effective slew rate compensation. Crowbar current is frequently used to control signal edge rates, but it has not been used to compensate for on-chip termination resistance variation before now.

The simplicity of the invention is unmatched by other compensation schemes. No additional circuitry is required, other than the compensation resistors themselves. The output driver control signals must be tuned to control the duration that the crowbar current flows, but this does not add requirements beyond what is needed for normal output drive control.

Likely Users of the Technology/Potential Infringement

This invention saves manufacturing cost, and allows the use of cheaper, simpler resistive elements to be used for on-chip signal termination. Any manufacturer of integrated circuits containing on-die termination devices for high-speed chip-to-chip signaling could benefit from this invention.

Infringement can only be detected by examination of the competitor's silicon. Since the Nwell resistor devices are relatively large, it could be possible to use a scanning electron microscope to determine whether the competitor's chip has implemented this concept. External detection through normal signal probing methods would be difficult.